Lithium transport modeling in a low power DIII-D plasma

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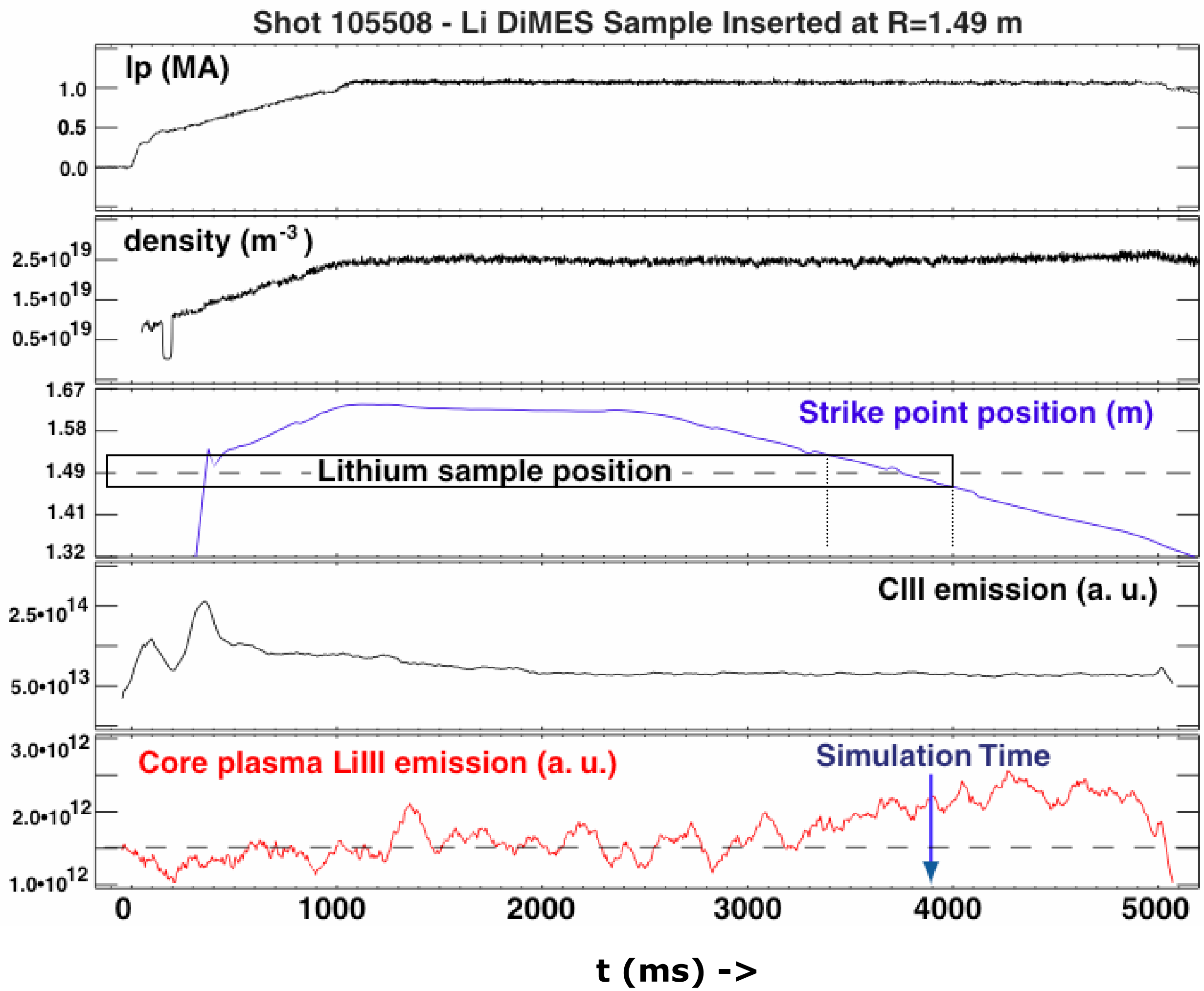
ALPS/APEX Meeting
Wednesday 6 November 2002,
Princeton Plasma Physics Laboratory, Princeton New Jersey

Lithium transport is being modeled in DIII-D with coupled fluid and kinetic codes

- Four specialized codes have been coupled to model Li sputtering and transport from a DIII-D DiMES sample
  - > background plasmas are simulated with the B2.5 / DEGAS fluid plasma / kinetic neutral deuterium code (L. Owen and R. Maingi at ORNL)
  - > Li sputtering sources are simulated with the gyro-kinetic WBC code (J. Brooks at ANL)
  - > Li transport is simulated by coupling the kinetic Monte Carlo Impurity (MCI) code to a B2.5 background plasma while using WBC Li sources (particle positions, velocities and charge states) as the initial conditions for the MCI simulation (T. Evans at GA and D. Finkenthal at Palomar)
- Simulations from the coupled codes will be compared to Li spectroscopic data from future DIII-D experiments where the edge Li concentration is increased to above 1% (the spectrometer resolution limit) by using very slow strike point sweeps across the Li sample.

The DIII-D strike point is swept across the Li DiMES sample center at ~3700 ms

- There is no significant increase in the edge LiIII brightness (from the λ = 114 Å line) when the strike point is swept across the Li DiMES sample.
  - > This implies that the outer midplane Li density does not increase by more than 1% (the resolution of the spectrometer) during the discharge.
- Slower strike point sweeps, with more core Li, are needed to benchmark the models.



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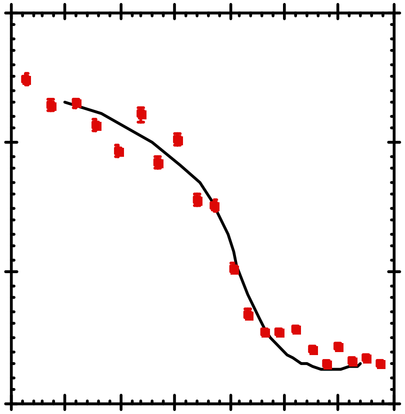
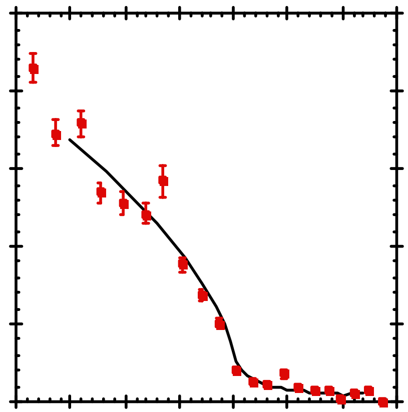
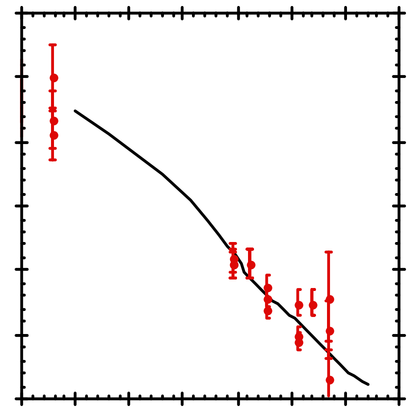
B2.5 / DEGAS simulation of 105508:3900 provide good match to experimental data

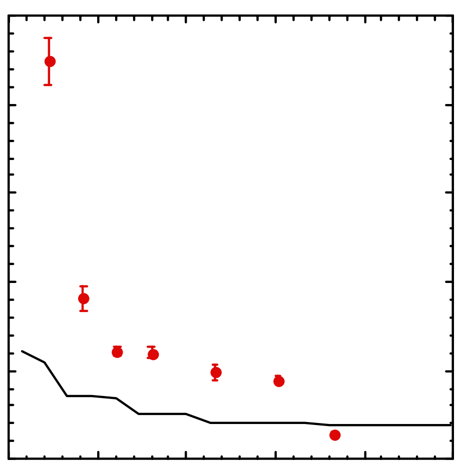
- **B2.5 equilibrium 2** matches the experiment relatively well:
  - > Total radiated power = 0.51 MW
  - > Power crossing separatrix = 0.81 MW
  - > Core particle efflux = 519 amps (B2.5)
  - > Core fueling rate = 519 amps (DEGAS)
  - > NBI fueling rate = 9 amps
  - > Average core particle confinement time = 0.12 s
  - > Integrated particle flux *inner divertor 2475 amps*, *outer divertor 2508 amps*
  - > Required radiation multiplier = 2.4
- Unity divertor recycling (R_{div-in} = $R_{div-out}$ = 1.0 > saturated targets) with pumping walls matched to midplane D_α also agrees well with measured divertor data for **B2.5 equilibrium 2**.
- **B2.5 equilibrium 1** (with R_{in} = 0.925 and R_{out} = 0.99) provides an interesting Li transport sensitivity test of MCI simulations.

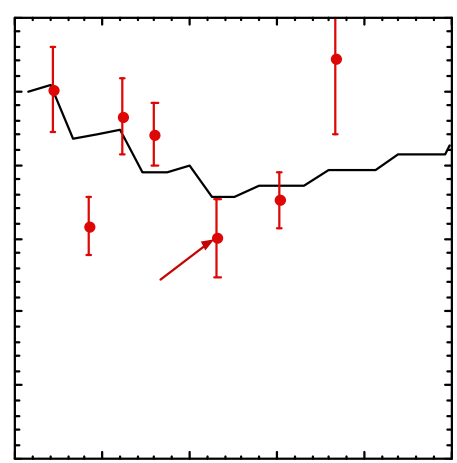
Background DIII-D DiMES Plasma Modeled and Supplied for Lithium Impurity Transport Analysis





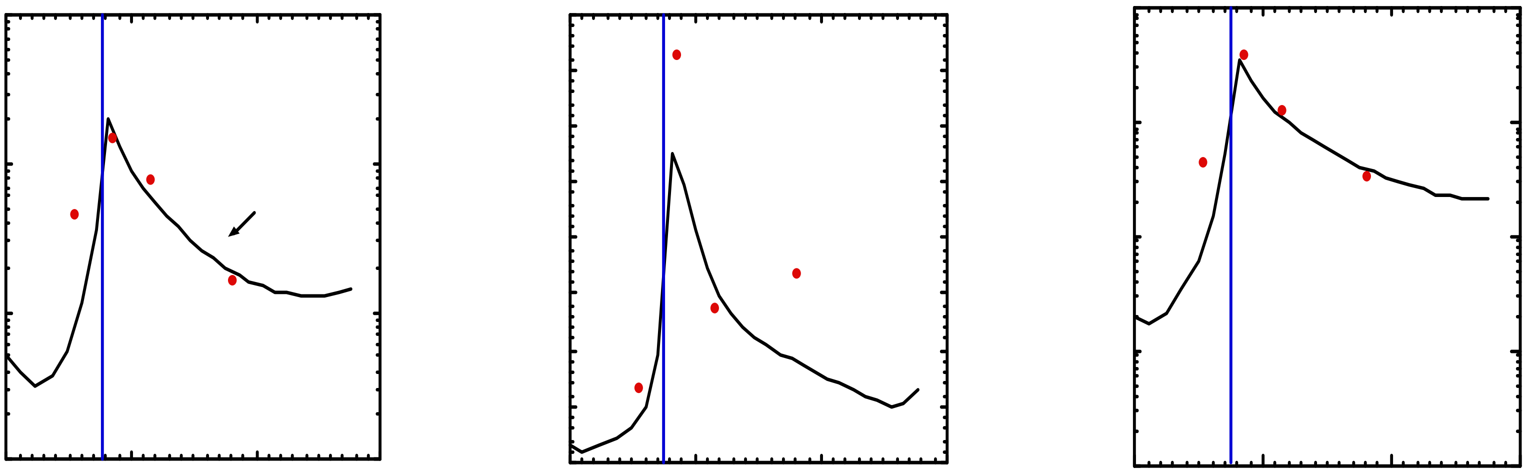


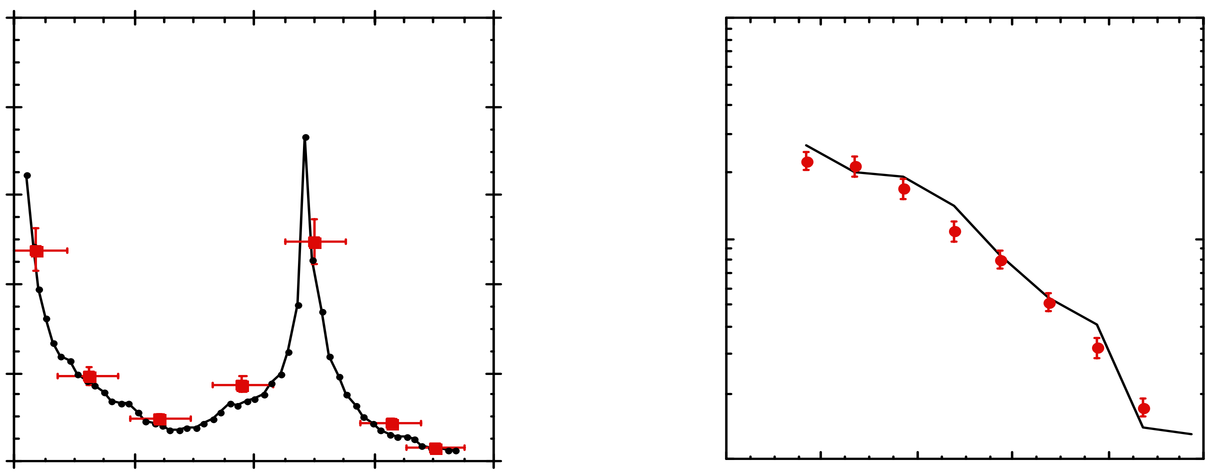




L. Owen

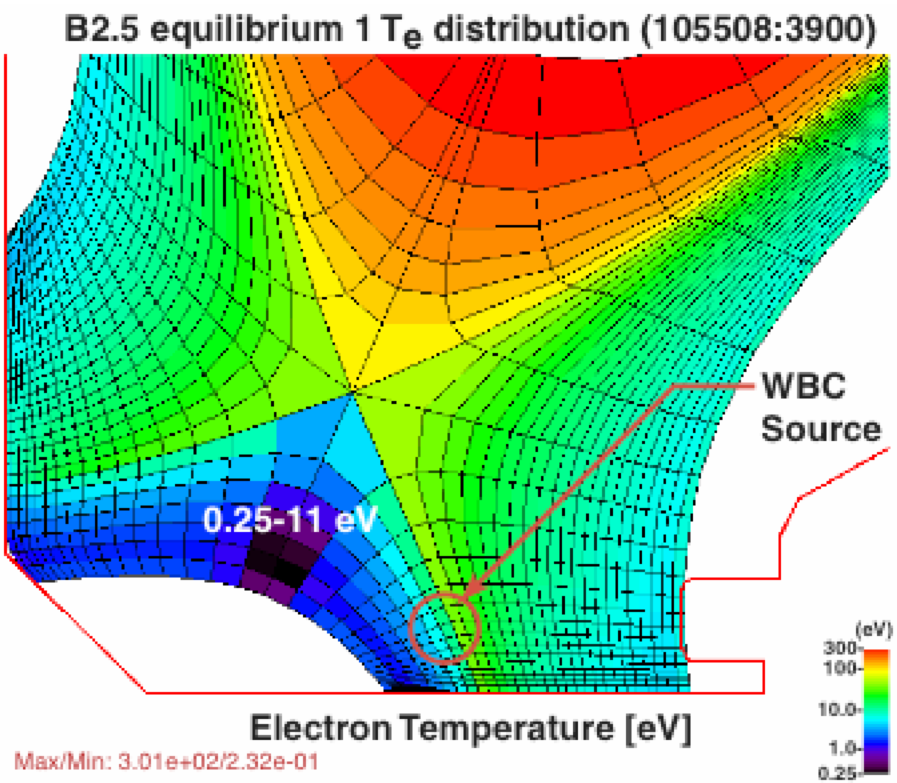
Background DIII-D DiMES Plasma Modeled and Supplied for Lithium Impurity Transport Analysis





L. Owen

Li sputtering source provided by WBC in the region ~5 cm above DiMES



WBC uses B2.5 D^+ flux to the Li sample and experimentally measured plasma parameters to produce the sputtered particle distribution above the DiMES probe.

MCI randomly samples 654 Li particle positions, charge states and velocities provided by the WBC code and follows them until they either pass through the inner core plasma boundary (ψ_N = 0.92) or are lost to a plasma facing surface.

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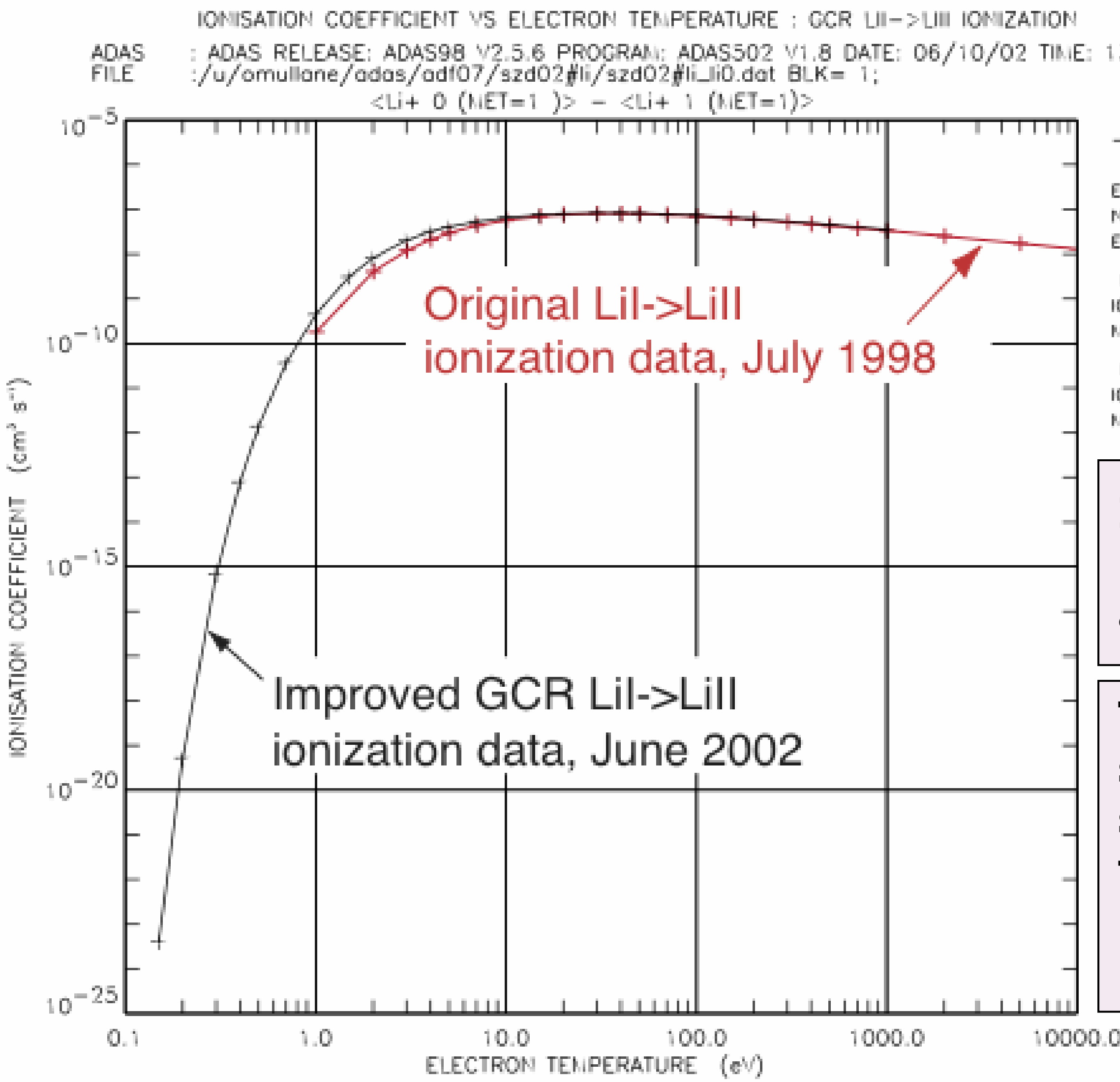
ADAS LiI->LiII ionization rates drop rapidly with T_e below 10 eV



--- IONISING ION INFORMATION ---

ELEMENT SYMBOL = Li
NUCLEAR CHARGE = 3
EFFECTIVE ION. PT.(cm-1) = -20854

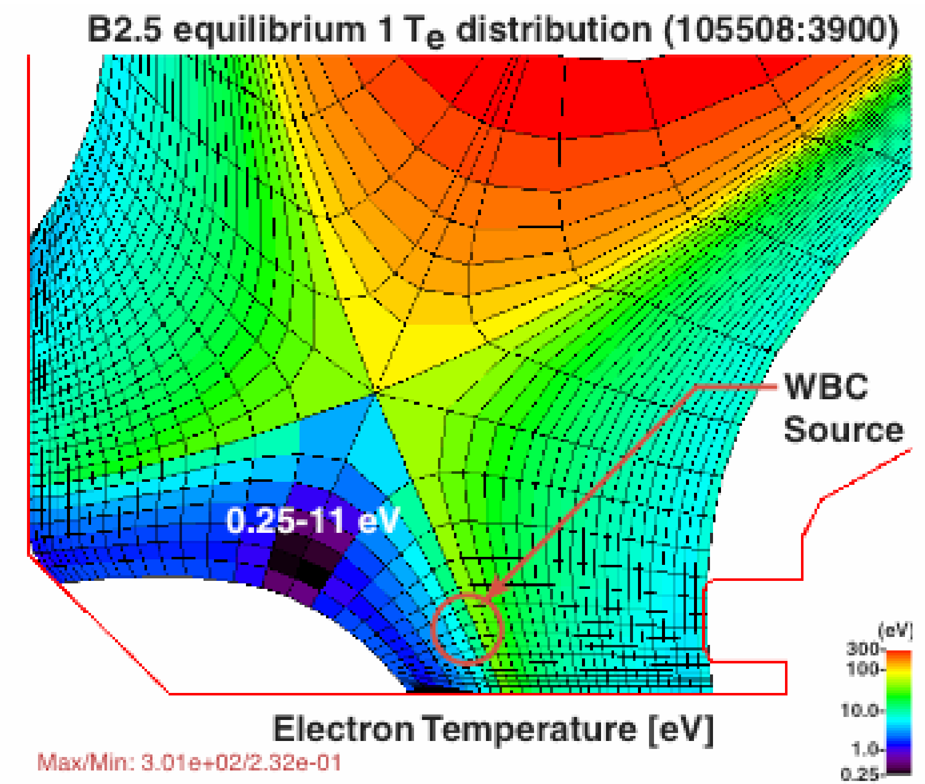
INITIAL STATE:
ION = Li+ 0
METASTABLE INDEX = 1

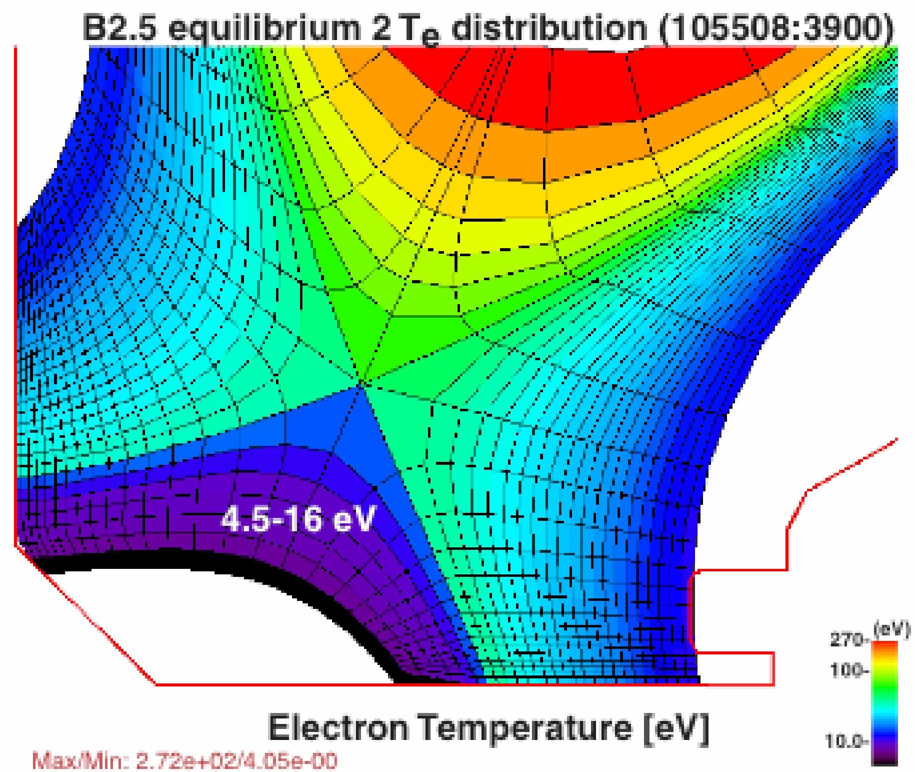
FINAL STATE:
ION = Li+ 1
METASTABLE INDEX = 1

Improved Lithium (GCR) ionization rate coefficients are ~2X larger at 1 eV

The B2.5 solution can significantly change the simulated Li transport through the private flux region if T_e resides in the 1-3 eV range.

The B2.5 T_e distributions in the private flux region are very sensitive to target recycling

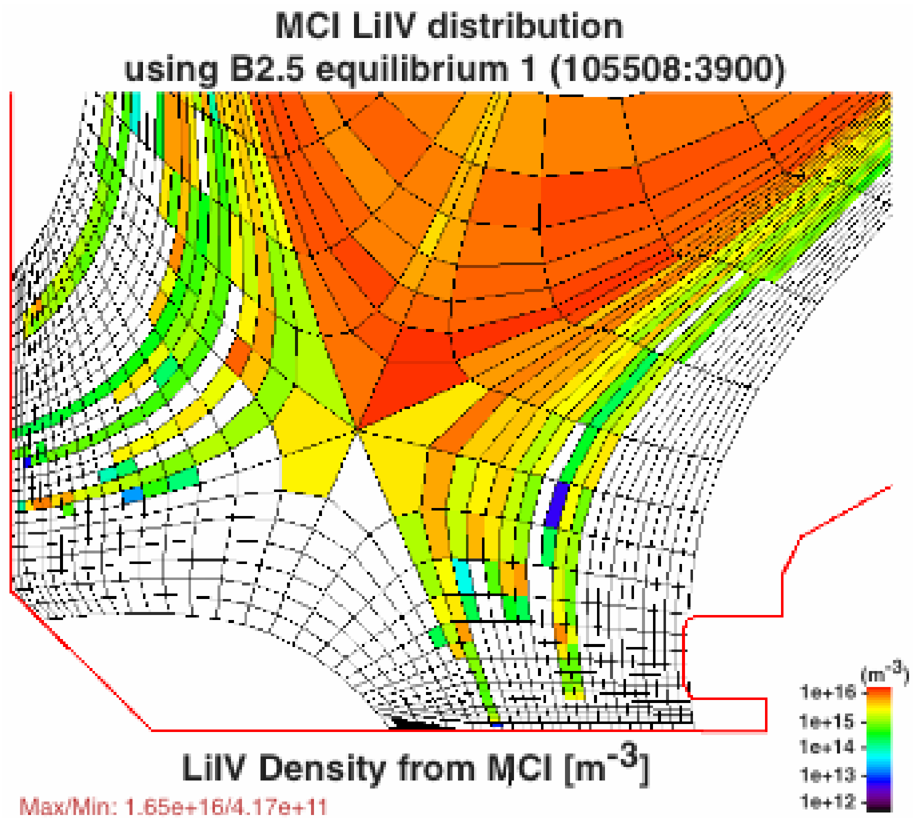




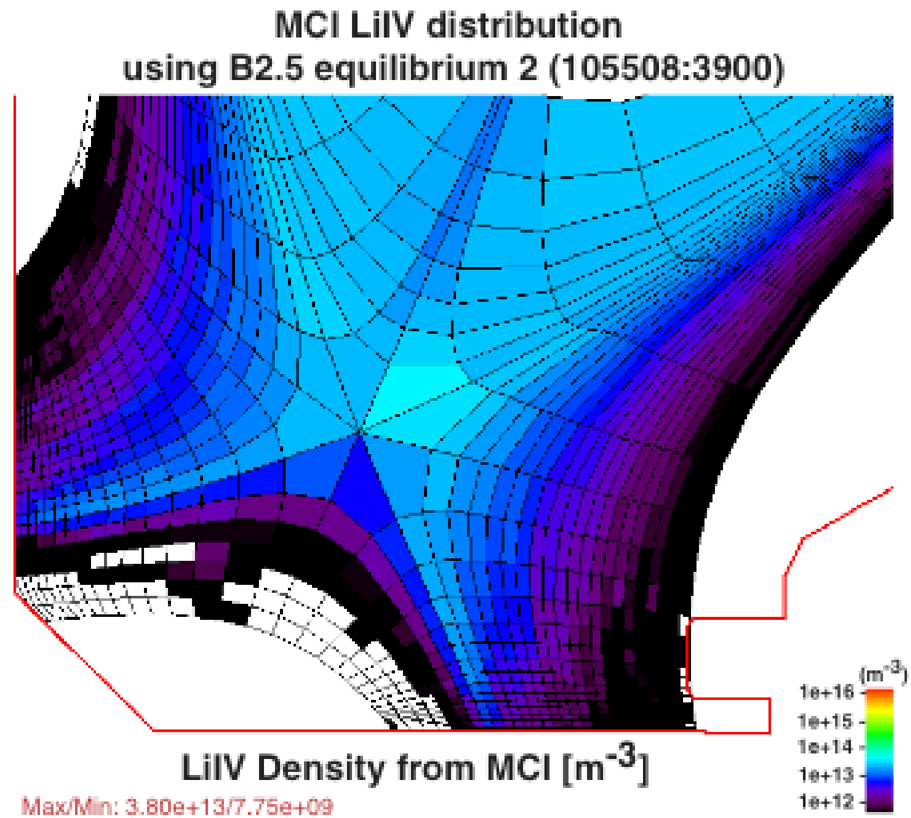
R_{div-in}=0.925 & $R_{div-out}$ = 0.99

R_{div-in}= $R_{div-out}$ =1.0
D_α matched at midplane

The Li core concentration calculated in MCI is extremely sensitive to the B2.5 private flux region solution



R_{div-in}=0.925 & $R_{div-out}$ = 0.99
Core Li concentration ~ 0.1%



R_{div-in}= $R_{div-out}$ =1.0
Core Li concentration ~ 0.0002%

Suggests that drifts may need to be included in plasma model

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Summary

- B2.5 / DEGAS was successfully coupled to WBC and MCI in order to study Li transport during low power L-mode DIII-D Li DiMES experiments
- The sensitivity of the B2.5 private flux solutions, to boundary conditions such as divertor recycling, is a key Li impurity transport issue that needs to be resolved in future work:
  - MCI indicates significantly more Li core fueling through the private flux plasma if T_e drops much below 10 eV (R<1). Why does T_e drop with R<1?
  - Improved private flux modeling (additional physics: drifts?) and better experimental data are needed to better understand the private flux solution
- Preliminary Li transport results indicate a core concentration increase ranging from 0.0002% to 0.1% depending on T_e in the private flux region.
  - While this variation is large (and very sensitive to the boundary conditions used in the fluid code), these results are in agreement with experimental data indicating there is always less than 1% Li in the edge plasma during the discharge being simulated.
- Future work will focus on quantitatively comparing simulated LiIII edge radiation from MCI with spectroscopic LiIII data from DIII-D during very slow x-point sweeps (where LiIII concentrations in the edge will be forced to exceed 1%).